Managing acid soils for reclaiming livelihoods in Ethiopia

What are the benefits

Increased yield
(In cereals)

30-40% increase with liming alone

50-100% increase when combined with ISFM

Healthier soils and crops

Increased **nutrient availability**

Improved **grain quality**

Improved soil **microbial activity**

Reduced **fertilizer costs**

Decreased Aluminum and Magnesium **toxicity**

Greater **pesticide effectiveness**

Why it is critical

41% of cultivated land In Ethiopia is affected by soil acidity[1]

28% of cultivated land is highly acidic (3.5 million ha)[1]

9 billion birr* per year is lost in foregone wheat production i.e. 17,000 birr every single minute[2]

Crop diversity is reduced as farmers restrict to acid-tolerant crops such as barley and potatoes

Abandoning of land and migration has been observed in areas of extreme acidity

Cost of inaction can be high impacting food security and income of smallholder farmers adversely.

Picture above shows the difference between farmers' practice with no lime (left) compared to ISFM with lime (right). Photo: GIZ-ISFM

**1birr= 0.035 USD*

How it can be addressed

3 complementary approaches are often employed in the management of acid soils:

- **Liming** – application of calcium and magnesium-rich materials from local sources
- Integrated Soil Fertility Management (ISFM)
- Acid-tolerant crops and varieties

The approach is dictated by rainfall patterns, soil properties as well as economic considerations.

(Source: 1. Getachew Agegnehu et al. 2018; 2. James Warner et al. 2018)

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General status of Ethiopian soils

Low in available **Nitrogen** and **Phosphorus**

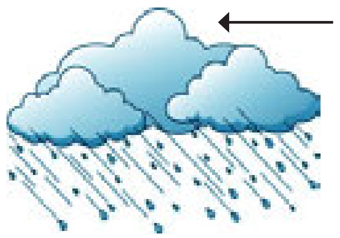
pH values mostly in the range of 4.5 to 6.5

High-altitude eroded soils and leached soils in the low-lying areas

- Acidic in reaction
- Poor in exchangeable cations
- Low in base saturation

Indicators of soil acidity

Soil acidification is the result of a complex set of processes caused both naturally and by human activity. It limits plant growth because of conditions that increase base element deficiencies, Phosphorus-fixation and toxicities of Aluminum, Manganese and Hydrogen ions.



Wet climate

LEACHING OF BASE ELEMENTS: High rainfall leaches the soil of base elements that prevent soil acidity such as:

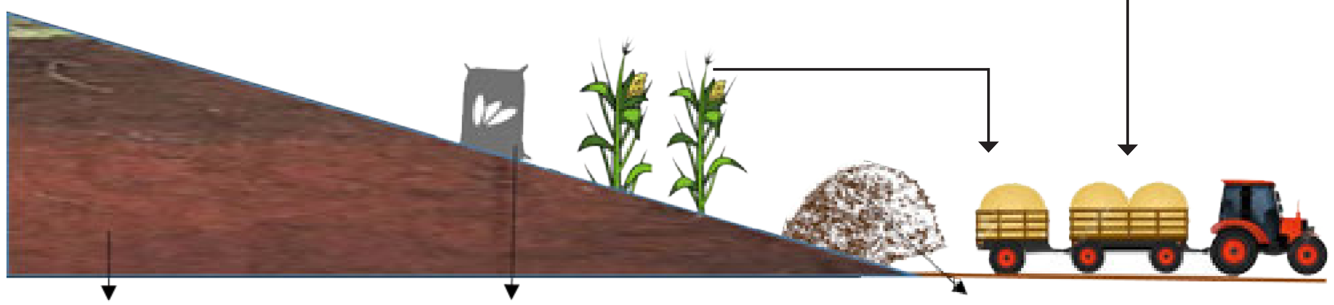
- **Calcium (Ca)**
- **Magnesium (Mg)**
- **Sodium (Na)**
- **Potassium (K)**

ALUMINUM TOXICITY: Soluble nutrients such as Ca and Mg are replaced by Aluminum (Al).

PHOSPHORUS-FIXATION: Fixation occurs when P reacts with other minerals to form insoluble compounds and becomes unavailable to crops.

High-yielding crops

REMOVAL OF BASE ELEMENTS BY CROPS: Crops absorb Ca, Mg, and K for their nutritional requirements during growth. As crop yields increase, more of these lime-like nutrients are removed from the field. Harvesting crops, especially forage cops, results in higher removal of the base elements.



Acid parent material

SOILS LOW IN LIME: Soils derived from weathered granite are likely to be more acidic than those derived from shale or limestone.

MINERAL TOXICITY: The principal hydrous oxides of the soils are Al and Iron (Fe). When soil pH decreases, these oxides through step-wise hydrolysis release Hydrogen (H+) ions resulting into further acidification.

Use of ammonium fertilizer

HYDROGEN ION TOXICITY: Transformation of some Nitrogen fertilizers into nitrate (NO_3) releases Hydrogen ions (H+) to create soil acidity.

REMOVAL OF BASE ELEMENTS: In effect, nitrogen fertilizer increases soil acidity by increasing crop yields, thereby increasing the number of basic elements being removed.

Decomposing organic matter

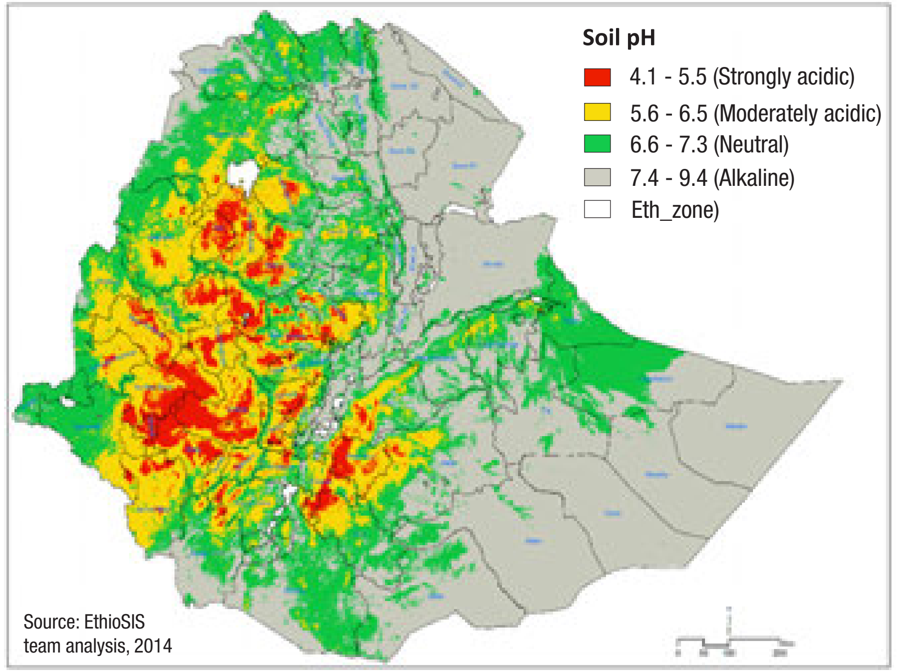
HYDROGEN ION TOXICITY: Soil organic matter or humus contains reactive carboxylic, enolic and phenolic groups that behave as weak acids. During their dissociation they release H+ ions. The formation of Carbon dioxide and organic acids during the decomposition also result in replacement of bases on exchange with H+ ions.

Symptoms of soil acidity in crops

- Poor plant vigor
- Uneven crop growth
- Poor nodulation of legumes
- Stunted root growth
- Persistence of acid-tolerant weeds
- Yellow/red leaf discoloration
- Increased disease incidence

Extent of soil acidity in Ethiopia

>80% *of the landmasses originating from Nitisols are acidic*



Examples of well-known areas severely affected include:

Oromia
- Gimbi
- Nejo
- Hosaena
- Sodo

SNNPR (Southern Nations, Nationalities and Peoples' Region)
- Endibir
- Chencha

Amhara
- Hagere-Mariam
- Awi Zone

Source: Sahlemedhin and Ahmed, 1983; Mesfin, 2007

Steps taken by the Ethiopian Government and partners

GTP (Growth & Transformation Plan) The lime initiative laid the foundation for much broader dissemination and impact of agricultural lime in Ethiopia through:

Groundwork

Successfully created awareness of, and demand for, agricultural lime among smallholder farmers in acid soil areas of the highlands.

Capacity building

Trained development agents and district agricultural experts in critical skills of soil sampling, lime application and in conducting demonstrations and popularizations.

Infrastructure

Establishment of lime crushers in selected locations. There are currently five lime crushers in three locations, with a total annual capacity of just under 20,000 tons.

Goal for 2020
226,000 ha
of acid soils to be treated

Plan for next five years
450,000-900,000 tons
of lime needs to be produced, distributed and applied to acid soils to meet the goal

Infrastructure needed
5 to 10 times
the current crusher capacity would be needed

Benefits of liming

- **Increases soil pH** and availability of Phosphorus, Molybdenum and Nitrogen
- **Eliminates toxicity** of Aluminum and Manganese.

Faba bean with lime.

Faba bean without lime.

Soil acidity management approaches

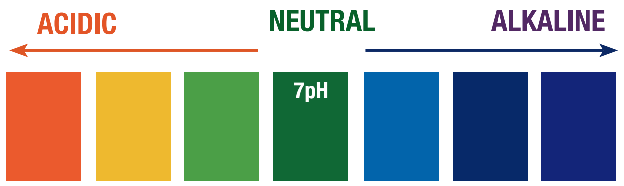

Photo: GIZ-ISFM

Diagnosing soil acidity

Periodical soil testing is needed when growing high-yielding crops. Testing identifies soil acidity early enough to change the pH

Steps include:
1. Soil sampling
2. Monitoring soil pH
3. Reaching target pH

What the pH score says



Liming acidic soils calls for application of calcium- and magnesium-rich materials to soil in the form of:

Marl | Chalk | Limestone | Hydrated lime

Decision guide for soil acidity management

Farms in high rainfall areas can be	Extremely acidic (<4.5pH)	Moderately acidic (4.5-5.5 pH)	Slightly acidic (5.5-6.5 pH)
Indicators checklist			
Type of farm	Abandoned farms	Low-yielding agricultural farms	Productive farm
Crop system	Rarely grows barley, potato or wheat; only weeds like *Rumex spp* grow	Grows coffee, teff, wheat, barley and potatoes	Grows coffee, teff, wheat, barley and potatoes
State of crop	Predominantly, crops dry up quickly, very poor yield	Stunted crops with low-yield	Productive with amendments
Crop symptoms	Excessive toxicity: Al (stunted roots) Mn (pale/ yellow leaves) Fe (brown spots on leaves)	Leaf discoloration (purple or dark green) caused by P-deficiency	Leaf discoloration (purple or dark green) caused by P-deficiency
Soil indicators	Shallow and hardpan (Degraded Nitisols, Luvisols, Acrisols, Alisols and Ferralsols)	Moderately fertile and wet (Nitisols, Luvisols, Acrisols, Alisols and Ferralsols)	Deep clay or loam (Mostly Nitisols; Alisols, Gleysols, Cambisols, Planosols and Ferralsols are also found)
What can be done	**Reverse the condition by:**	**Manage the soil by:**	**Maintain and improve the soil by:**
System shift	Shift to pasture/livestock systems		
Liming	Liming with high rate (>6 ton / ha) (To be done after all the other interventions)	Whole farm application of lime (4-5 t/ha), repeat every 5 years, OR rotational application of lime, row application (about 2.5 t/ha)	Maintenance, rotational application of lime (about 2.5 t/ha)
Fallowing + legumes	Fallowing with deep-rooted legume trees (e.g. *Acacia decurrens; Erythrina spp; Sesbania spp*)	Short season fallow with deep rooted legumes (e.g. Alfalfa, Lupin)	Short season fallow with deep rooted legumes (e.g. Alfalfa, Lupin)
Water guide	Proper drainage	Proper drainage	Proper drainage
Fertilizer usage		Avoid ammonium-based fertilizers	Avoid ammonium-based fertilizers

How to apply lime

There are options available to incorporate lime ranging from **surface application** and **deep rip** to **direct injection** and **shallow incorporation**. The choice depends on the farm. Raw application of lime reduced the lime demand significantly.


Photo: Dept. of Primary Industries and Regional Development, Govt. of Western Australia

Complementary strategies

Integrated soil fertility management: In acid soils, where Phosphorus (P) fixation is a problem, application of **Farm Yard manure** (FYM) releases a range of organic acids that can form stable complexes with Aluminum and Iron thereby blocking the P retention sites and releasing P.

Tolerant crop and pasture species

In extreme acidic soils Triticale rye with hybrid wheat was found to be producing a good crop.

For effective reclamation of acid soils:

Determine the amount of lime:

Application of 2-5 tons of lime per hectare annually has been reported to be adequate to maintain the level of Ca and Mg in the soil under continuous cropping.

Determine the frequency of liming

At higher rates, residual effects of liming are expected to **last for five to seven years.** When a high rate of lime is recommended, (>6 tons/ha) biennial application may suffice.

Purity determines rate of application

If the purity of liming material is 80%, then **recommendation rate must be adjusted** by multiplying by 100 and dividing by 80.

Smaller-size material acts faster

The finer the lime material the faster is the correction of soil pH.

Soil type determines the lime amount

Clay soils, particularly nitisols, need more lime to correct the pH. Due to high organic matter they have a larger reservoir than sandy soils.

GTP II targets: Reclaim 226,000 hectares of acidic soil

For every **1birr** invested today, a NPV* return of **5.2 birr** is projected

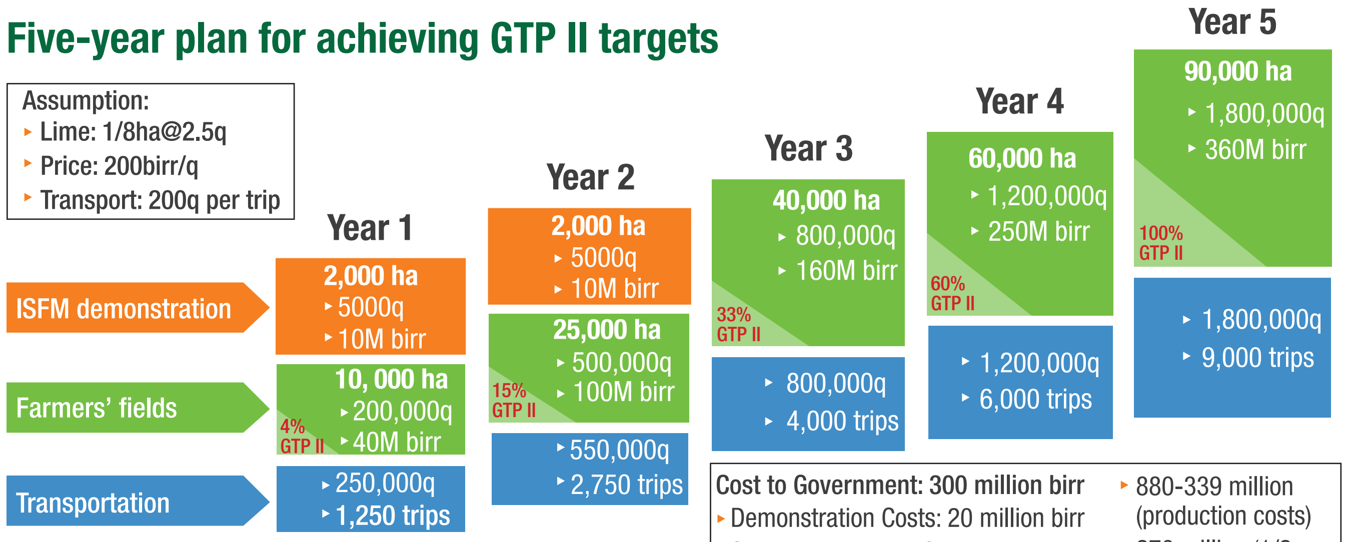
Production	Distribution to sellers	Sale of lime + ISFM	Application & planting	Harvesting	National benefits
Public/private lime crushing: **452,000 tons**	Developed private transportation networks	Public/private agro-dealers & cooperatives	1 ton lime per 1/2 hectare plot for 452,000 farmers	40% yield increase with lime (ISFM needed)	5 year production 8.5 M q wheat
Cost 339 million birr	Cost 475 million birr	Lime cost 45 million birr	Total lime cost 859 million birr	Benefit **1st Year production** 3.8 q wheat Net income: 1,000 birr	Benefit NPV 5 year production 8.5 M q wheat 6.6 billion birr sold
Unit cost per ton 750 birr	Unit cost per ton 1,050 birr	Unit cost per ton 100 birr	Total lime 1,900 birr Total application 900 birr	**NPV 5 year production** Net income: 11,849 birr Total returns: 523%	

** Net present value*

Incentives for scaling up

- **Strong lime production** capacity of Ethiopian Cement Industry
- **Farmers willing to pay** for lime (EIAR, IFPRI, 2016)
- **Employment of Youth** (loading, local transport, application, retailing…)
- **Increasing demand** for lime from various regions and their communities

Five-year plan for achieving GTP II targets

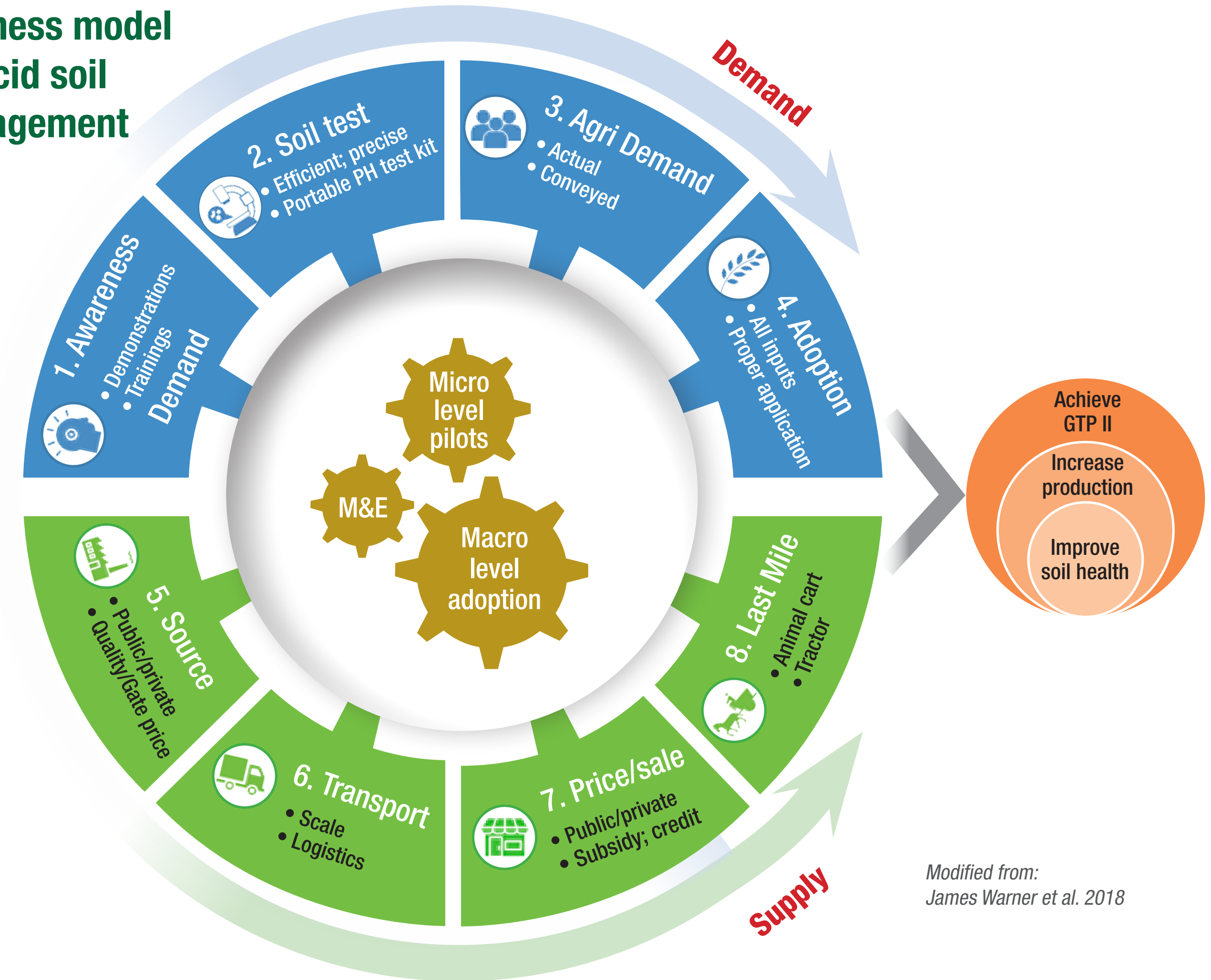


Cost to Government: 300 million birr
- Demonstration Costs: 20 million birr
- Subsidy to achieve GTP II targets: 273 million birr
- 880-339 million (production costs)
- 270 million (1/2 transport costs)
- Average subsidized price per q: 140 birr

James Warner et al. 2018

1birr= 0.035 USD

Business model for acid soil management



Modified from: James Warner et al. 2018

Lime Production and Supply Chain Options

(Task Force Report, 2018)

Lime Supply Options		Production	Transport	Distribution
3 million ha Acidic Soil Coverage	Direct sale	Private cement factories	Private sector Transport	Unions/public associations, woreda* agriculture office, agro-dealers
	Credit	Private cement factories and public lime crushers through government support	Government supported private sector transport	Woreda agriculture office, public mobilization, with the support of partner institutions
	Project	Private cement factories through project support	Project supported private sector transport	Unions/public associations, woreda agriculture office, agro-dealers

**District*

Results of farmer field demonstrations across the Ethiopian Highlands (Amhara, Oromia, SNNPR and Tigray)

Faba bean							
		Grain yield (t/ha)			Stover yields (t/ha)		
Year	N*	ISMF + lime	Minus lime	Increase (%)	ISFM + lime	Minus lime	Increase (%)
2016	45	2.2	1.3	78	4	2.5	60
2017	31	2.9	1.3	115	4.9	2.7	80
2018	9	4.6	2.6	80	5.4	2.5	121
Total/ weighted average	85	2.7	1.4	88	4.5	2.6	74

Wheat							
		Grain yield (t/ha)			Residue yields (t/ha)		
Year	N*	ISMF + lime	Minus lime	Increase (%)	ISFM + lime	Minus lime	Increase (%)
2016	100	4.4	2.5	80	7.5	4.7	59
2017	66	5.4	3.3	63	8.8	5.7	55
2018	58	5.0	2.9	73	8.7	4.8	80
Total/ weighted average	224	4.9	2.8	71	8.2	5.0	63

**Number of experiments* *Minus lime=farmer practice (without lime)*

Maize							
		Grain yield (t/ha)			Residue yields (t/ha)		
Year	N*	ISMF + lime	Minus lime	Increase (%)	ISFM + lime	Minus lime	Increase (%)
2016	72	8.3	4.5	86	14.2	8.4	69
2017	47	9.1	5.7	59	17.6	12.4	42
2018	18	8.0	5	61	13.7	9	52
Total/ weighted average	137	8.5	5	71	15.3	9.9	55

Teff							
		Grain yield (t/ha)			Residue yields (t/ha)		
Year	N*	ISMF + lime	Minus lime	Increase (%)	ISFM + lime	Minus lime	Increase (%)
2016	63	2.2	1.3	70	5.6	3.8	46
2017	25	1.7	1.0	69	4.6	3.4	34
2018	8	1.9	1.2	56	4.3	2.4	75
Total/ weighted average	96	2.0	1.2	68	5.2	3.6	46

Recommendations

- **Need for a National Movement in Reclaiming Acid Soil:** This mission needs to be taken up with urgency as part of the solution for wheat import replacement and enhanced productivity.
- **Lime Production, Supply and Distribution:** Excavation, production, distribution and application of lime should be more consistent with current GTP II targets and the need for greater supply to meet the needs of the full acid soil problem should be developed (public-private partnership is strongly recommended).
- **Farmer Awareness and Support:** Development of enhanced government services that facilitate farmer awareness, acid soil diagnosis, access to local acid soil experts and availability of training packages and local demonstrations, assistance with last-mile delivery and the availability of financing and credit to smallholder farmers for lime procurement and application.
- **The Need for Targeted Application:** Refinement of a comprehensive acid soil treatment and management package (lime, improved seeds, fertilizers, organic matter management, improved agronomy).
- **Comprehensive Acid Soil Policy:** Beyond just targets (as included in GTP II), a fully developed government policy that addresses the needs of an efficient and sustainable acid soils reclamation strategy as well as complimentary services (research support, inputs, credit, etc.) is needed.

Limestone quarry at Guder, Oromia.

- **Lime Delivery Business Model:** Develop an efficient and sustainable lime delivery system that balances cost effectiveness with widespread farmer adoption and job creation.

Suggested next steps

- National campaign for lime promotion
- Minimize free distribution of lime, except for demonstrations
- Continue farmer demand creation for lime, particularly in the most-affected regions
- Develop sustainable lime delivery mechanisms (Proactive Task Force)
- Agree on pricing mechanism (subsidy/credit for lime) – Policy decision is needed.

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